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Falling of Wheat Culms Due to Lodging, Buckling, and Breaking[1]

By

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THE losses each year from the falling of wheat and other small grains as the result of lodging, buckling, and breaking of culms are considerable, and in some years and in some areas they are of critical importance. The various causes, including storms, diseases, insects, rank growth, and inherently weak stems, frequently have been confused. The purpose of this circular is to describe the various symptoms and conditions, as learned through scientific research, to aid in recognizing the causes. The discussion here is confined to wheat, although similar troubles may occur also in oats, barley, and rye.

SUMMARY

The bend that accompanies fallen wheat culms may be gradual, a buckle, or a complete severance of the culm. The extent of falling in a field may range from a few individual culms to complete mass falling.

Ordinary lodging is a mass falling and usually is the result of rank growth, storms, or inherently weak stems. The bend accompanying it is usually gradual. Mass falling, similar in appearance to ordinary lodging, may be caused by severe attacks of the cercosporella foot rot of the Pacific

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[1] Cooperative investigations of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, and the Kansas Agricultural Experiment Station. Contribution No. 327, serial No. 77, Department of Botany, Kansas Agricultural Experiment Station.

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Northwest or by severe attacks of leaf and stem rust. The bend in these cases is a buckle.

Individual culms may buckle (1) as a result of drowning, hail injury, or overripeness; (2) from such diseases as leaf and stem rusts, take-all, dry-land foot rot; or (3) following infection of nodes by *Helminthosporium* sp. or *Septoria nodorum.* More general buckling and breaking or severance of culms may be caused by subfreezing temperatures or hot winds and drought, or by attacks of such insects as the hessian fly, wheat jointworms, billbugs, or sawflies.

EXPLANATION OF TERMS

Lodging is commonly referred to as that condition in which the culms in large areas of wheat bend at or near the surface of the ground (fig. 1). The bending may vary in degree from a slight deviation from the perpendicular to a nearly prostrate condition, though the term is not commonly applied unless the deviation is considerable. The bend in most cases is not acute but gradual. If the lodged condition persists for a considerable time, some of the bends may become buckled. Occasionally the term "lodging" is used in a general sense, referring to any fallen stems regardless of cause or condition, but for purposes of clarification it seems desirable to refer to lodging as the condition described above in order to distinguish it from "buckling" and "breaking."

The word "buckle" means the same as the terms "break" or "breakover," as found in some literature (*4, 9*).[2] "Buckle" is used because it gives a specific description of certain symptoms. The term is applied when there appears to be so definite a collapse or deterioration of the culm tissue that the culm, unable to support itself and the head, falls over with a sharp bend or near break in one or more places. The collapse may occur at any point above the ground surface.

The weakest parts of the culm are in and immediately above the joints or nodes. It is there that buckling is most likely to occur. Sometimes the culms break either partly or completely, which permits the severed or nearly severed culm and attached head to fall over. This condition, referred to as "breaking" or "breaking over," may occur originally, or follow the buckled condition, the break occurring at the point of buckling.

In the literature "crinkle joint" refers to two conditions, one a buckle in a node due to disease in that node (*6, 7*) and the other an upright growth of the head following a buckle in the internode below (*9*). The latter is sometimes called "elbow joint."

LODGING

Lodging of grain is a well-known phenomenon. It occurs commonly where the growth has been rank, as on soils rich in nitrogen and well supplied with moisture. The tendency to lodge varies greatly in different crops and varieties. Several workers, including Atkins (2) and Bartel (3), have published results of studies on varietal differences and the relation of culm characteristics and of the stage of growth to lodging.

Some varieties having very stiff straw lodge very little even under conditions favoring rapid lush growth; others having very slender or weak culms

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[2] Italic numbers in parentheses refer to Literature Cited, p. 15.

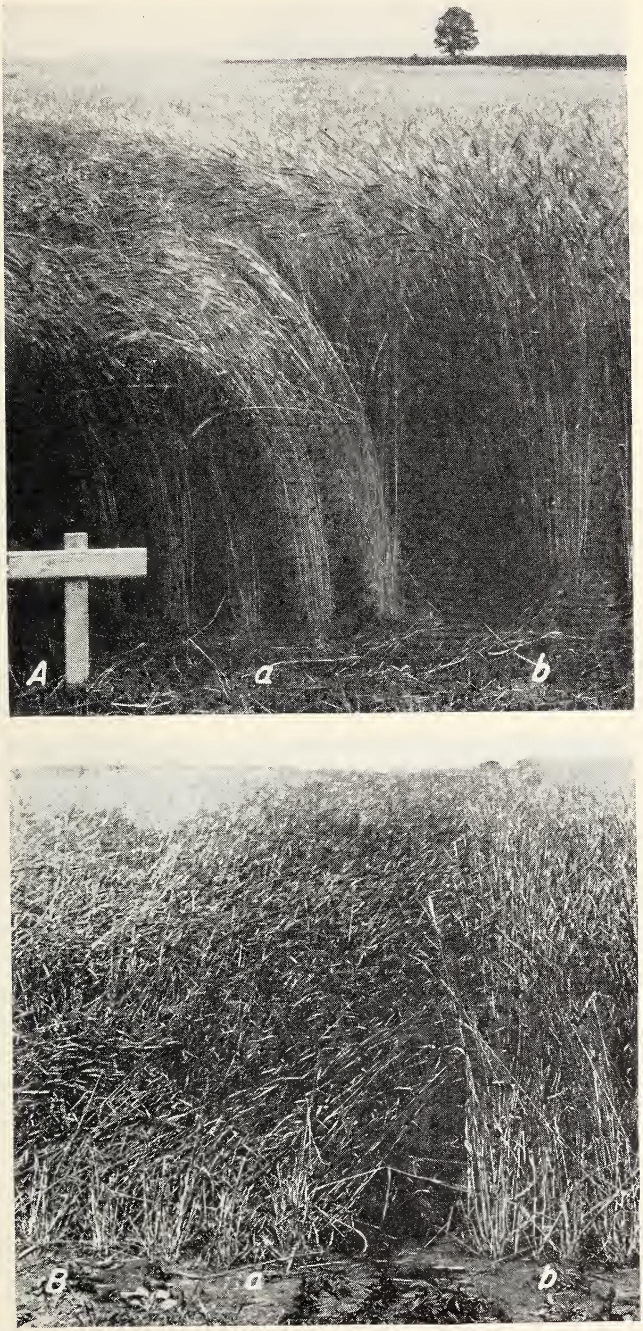

Figure 1.—*A*, *a*, Wheat variety showing tendency to lodge; *b*, erect variety. *B*, *a*, Wheat variety badly lodged; *b*, erect variety. Agronomy Farm, Kansas Agricultural Experiment Station.

lodge easily. In wheat, such lodging usually, though not always, occurs after heading but before maturity. Wind, beating rain, and the weight of adhering water all promote lodging. In most cases, lodging occurs quickly, as during a storm, and the culms are bent until they are prostrate or nearly so. Also the plants may lodge because of inadequate root anchorage (*17*), in which case the culm is bent either not at all or but little. In some cases, particularly in varieties having somewhat weak straw, the straw goes down rather gradually (fig. 1, *A*).

Lodging may be permanent or temporary. Wheat that has lodged because of a storm often becomes partly or nearly upright again with the return of clear weather, particularly if the stems are healthy and not too ripe. This recovery is brought about by the natural elasticity of the culm or by a growth in the lower side of the nodes that turns the stems upward. Grain lodged because of succulent growth and continuous wet weather or inherently weak culms usually remains lodged until harvest (fig. 1, *B*, *a*). Grain that has been lodged for some time provides favorable conditions for such diseases as mildew, scab, and leaf and stem rusts, and provides ideal conditions for armyworms. Such grain seldom if ever fills well. Temporary lodging causes little if any damage. If lodging is prolonged and the plants are nearly prostrate the gradual bend in the culms of many plants may become a buckle.

BUCKLING AND ITS CAUSES

Buckling apparently may be caused by any condition that checks the development of the culm or damages its structure. The source of the trouble may not be near the buckled area. Damage to roots can cause a buckle above the top node. This was demonstrated by an experiment in which the roots of wheat plants in the soft dough stage were injured with formaldehyde. Most of the culms buckled just above the top node and some just above the next node below it (fig. 2). Usually the buckling of the straw takes place slightly above a node. The condition referred to as buckling may occur as a result of wet weather or storms on overripe wheat. Apparently this is due to a deterioration or partial decay of the mature straw (fig. 3).

Buckling may occur also as a result of drowning (fig. 4), especially in low places during wet seasons. Such buckling was particularly prevalent in some fields after a flood in the Kaw River Valley, Kans., in 1935, when the grain was in the soft-dough stage. The crowns and roots of the plants had been under water for several days. Most of the buckling occurred at the top node (fig. 4), but the nodes were not discolored and apparently were not infected with disease. Apparently, plants near maturity or those not yet headed do not buckle when killed by drowning. Drowning usually may be identified by other evidence of flood conditions, such as topography, puddled soil, or deposits of debris or silt.

DISEASES

Cercosporella foot rot.—Falling accompanied by buckling is caused by the cercosporella foot rot fungus *Cercosporella herpotrichoides* Fron. The disease is also called the Columbia Basin foot rot, since it occurs only in the Pacific Northwest (fig. 5). In certain seasons favorable to the development of this disease, buckling is so extensive that falling may be confused

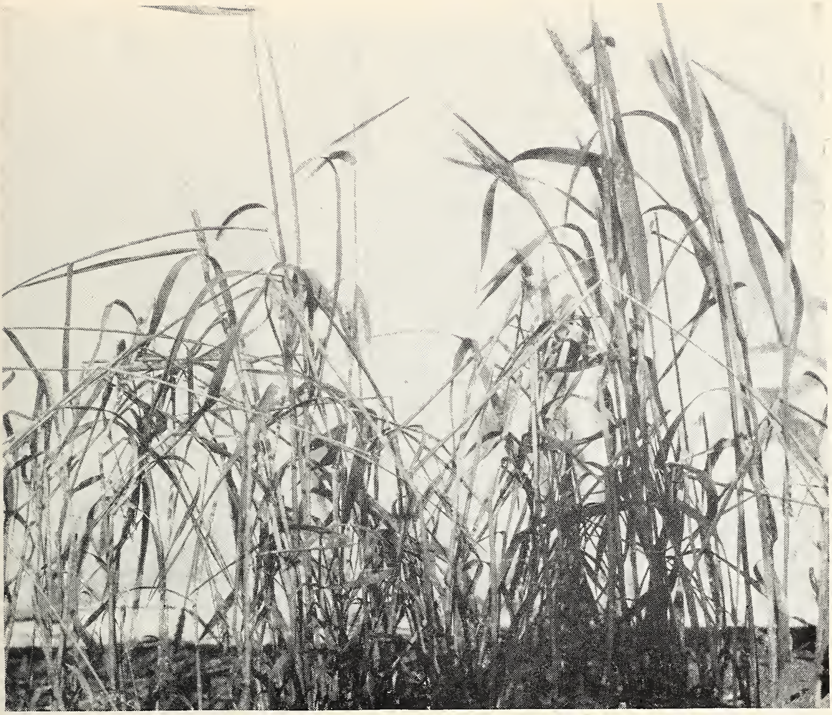

Figure 2.—Buckling of wheat culms at the top node due to injury to the roots by formaldehyde.

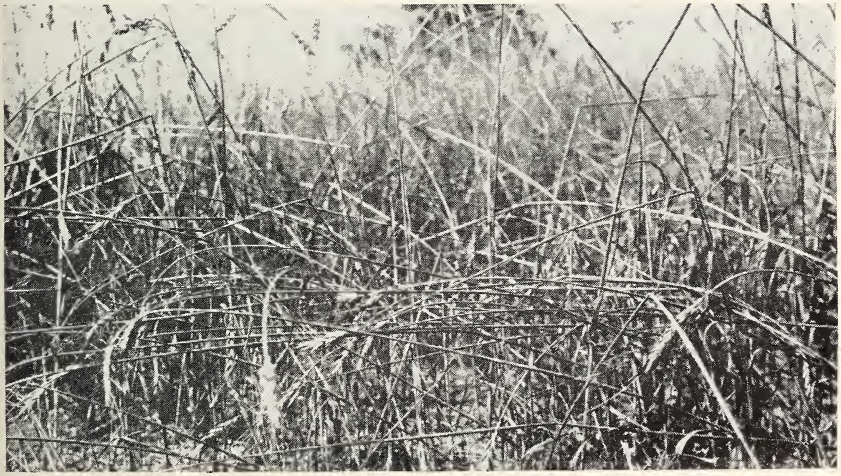

Figure 3.—Falling of wheat culms caused by overripening and wet weather. Virginia Agricultural Experiment Station.

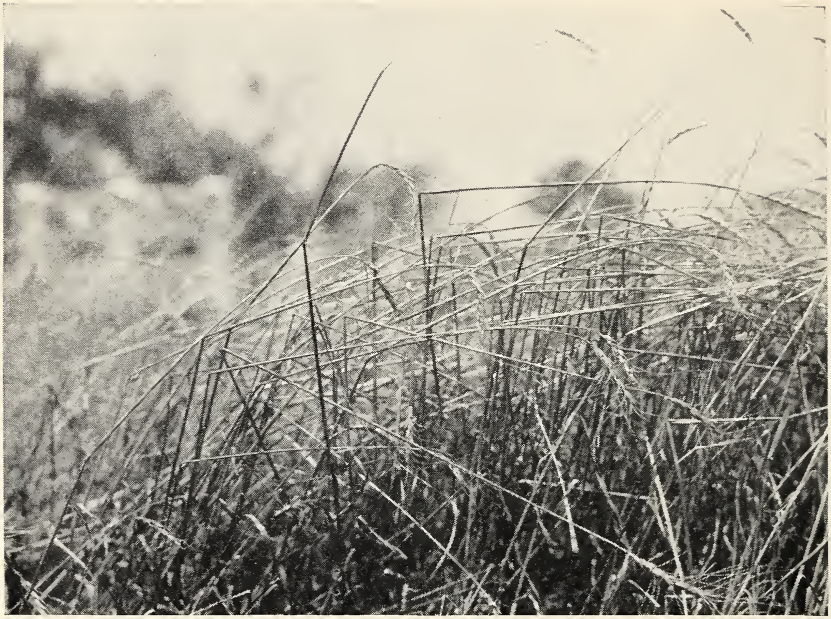

Figure 4.—Buckling of wheat culms following drowning, Herington, Kans., 1938.

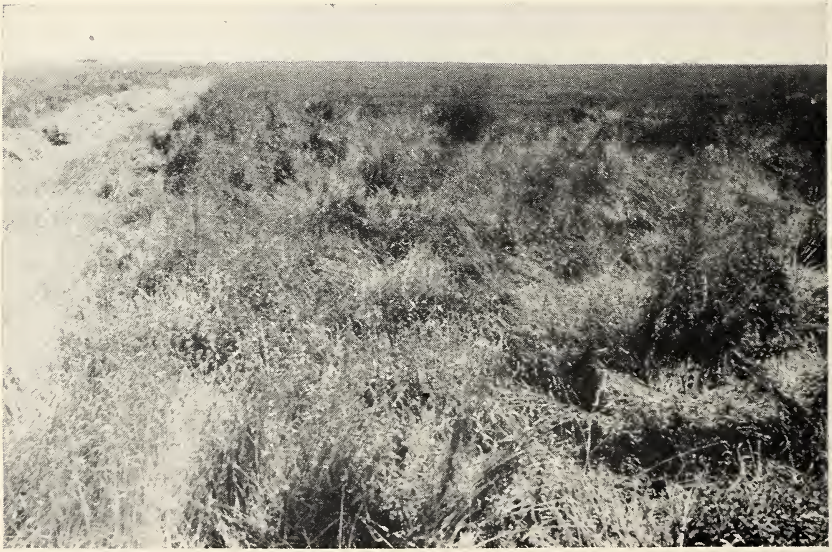

Figure 5.—Falling of wheat culms caused by attack of the cercosporella foot rot. Grande Ronde Valley, Oreg.

with ordinary lodging. The culms near the base are so weakened by attacks of the fungus that the plants go down in a tangled mass after they come into head and are unable to rise again. The bend is a buckle accompanied by considerable browning and usually occurs in the lower internodes (*10*, *13*, *14*, *15*). Only occasional culms fall when this disease is mild.

Rusts.—A fairly common cause of falling is severe attacks by stem rust (caused by *Puccinia graminis tritici* Pers.) and leaf rust (caused by *P. rubigovera tritici* (Eriks. and E. Henn.) Carleton). The bend in the culm is a buckle. Such buckling appears to result from the arrested development of strengthening tissue of the stem, or from the wilting or deterioration of the culm, following the invasion of rust fungi.[3] The buckling often occurs near the top node soon after flowering. The extent of falling caused by rusts depends on the time and degree of infection. In an experiment involving artificial inoculation with leaf and stem rusts, Kawvale wheat fell badly with an infection of 60 percent leaf rust and 45 percent stem rust. A selection from a Marquillo × Kawvale hybrid under the same conditions but with only 10 and 5 percent stem and leaf rusts, respectively, did not fall (fig. 6, *A*, *b*). Turkey (C. I. 1558),[4] with 85 percent leaf rust and 80 percent stem rust, fell nearly 100 percent (fig. 6, *B*). Each of these rusts alone has been observed to cause buckling near the top node. It appears that for rust to cause falling, infection must take place relatively early. Early infection with stem rust ordinarily does not occur in the winter wheat area under field conditions and hence falling in winter wheat due to this disease is rather infrequent. It more commonly follows early heavy stem rust attacks. Under conditions especially favorable for stem rust large areas of wheat in a field may fall in a tangled mass similar in appearance to wheat falling due to the cercosporella foot rot. Falling of this kind was observed near Colfax, Wash., in 1944 (fig. 7).

Take-all and dry-land foot rot.—Buckling at the upper node in wheat is sometimes associated with attacks by the take-all fungus (*Ophiobolus graminis* Sacc.) (fig. 8). This fungus attacks the roots, the subcrown internodes, the crowns, the lower part of the culms, and the lower leaf sheaths, but not the upper parts of the culm where the buckling occurs. Buckling may also be associated with the dry-land, or western, foot rot (cause not determined) which attacks the roots and crown tissues but not the culms where the buckling occurs. In both cases the buckling at the top node has been observed as similar to that associated with drowning and appears to follow the death of tissue in the lower parts of the plant as a secondary effect of foot-rot diseases.

Crinkle Joint

In the type of crinkle joint caused by diseases (*7*, *8*) the nodes are buckled and discolored and fungi have been commonly isolated from them, especially a species of *Helminthosporium*. The crinkle joint condition has been reproduced by artificial inoculation with this fungus. *Septoria nodorum* Berk., a fungus that causes also the wheat disease known as glume blotch, causes considerable buckling during some seasons. This buckling usually occurs in the top node and may be identified by the dark, discolored, shrunken nodes and the small black, inconspicuous dots in them, which are the fruiting bodies of the fungus.

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[3] Johnston, C. O. Unpublished manuscript.

[4] C. I. refers to accession number of the Division of Cereal Crops and Diseases.

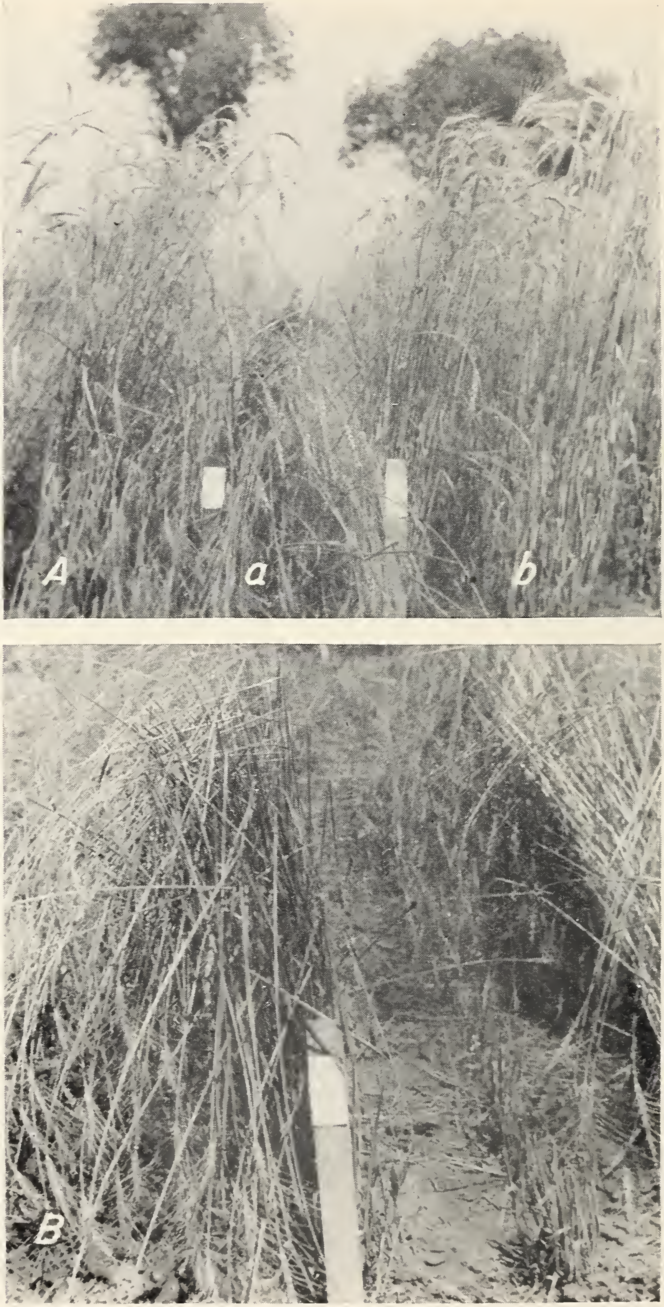

Figure 6.—*A*, *a*, Falling of culms of Kawvale wheat caused by heavy stem and leaf rust infections; *b*, less heavily infected Marquillo × Kawvale wheat remaining erect. *B*, Fallen Turkey wheat (C. I. 1558) heavily infected with both leaf and stem rusts. Rust nursery, Manhattan, Kans. (Courtesy of C. O. Johnston.)

Another type of crinkle joint, sometimes called elbow joint, is not caused by disease. This refers to a condition in which there is a buckling above the next to the top node, followed by an upward turn at the top node. This is believed to be caused by very severe windstorms, since all the falling at the buckle is in the direction of the wind.

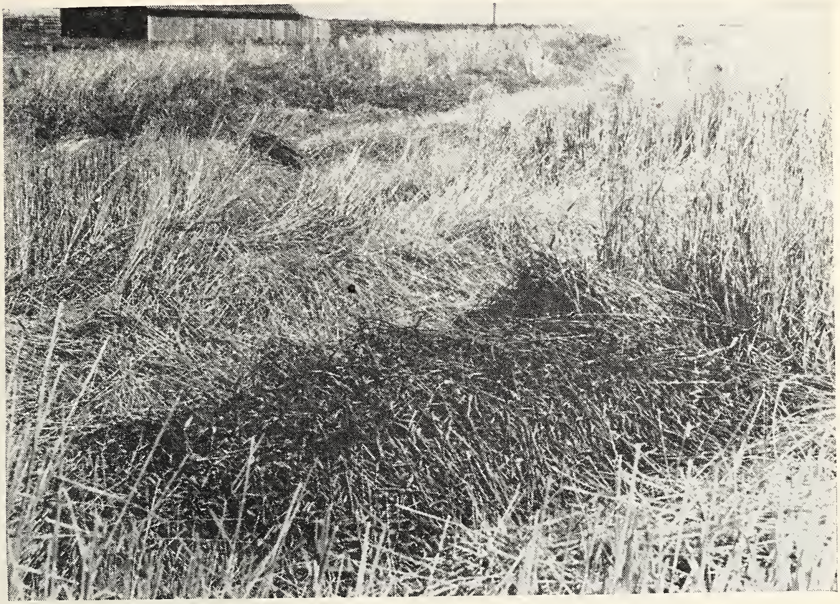

FIGURE 7.—Fallen and tangled wheat weakened by a severe attack of stem rust, near Colfax, Wash., 1944. (Courtesy of the Bureau of Entomology and Plant Quarantine, Agricultural Research Administration.)

HAIL

Small-grain culms may fall as a result of mechanical injury, such as that caused by hail (*9*). The hailstones may cause a buckle at any point along the internodes but not at the nodes (*7*). White bruised spots on the leaf sheaths, stems, or heads and a ragged appearance of the wheat are safe criteria of hail injury. Buckling occurs at many of these injured spots. Bruises occurring above the top node often produce so-called white heads. When hail injures wheat while the heads are in the boot, the heads often are caught in the boot and the tops of the culms are badly bent and the heads curled after they emerge. This is most noticeable in bearded varieties. The buckle in some culms may become a break when windstorms follow hail injury. This is due to continuous bending of the culm back and forth at the weakened buckled point.

Cold and Drought

Buckling of winter wheat culms in the lower internodes may be caused by subfreezing temperatures when the culms are elongating. If not killed, such injured culms may turn upward by growth of the nodes just above the point of buckling, resulting in a sprawling growth of the plants.

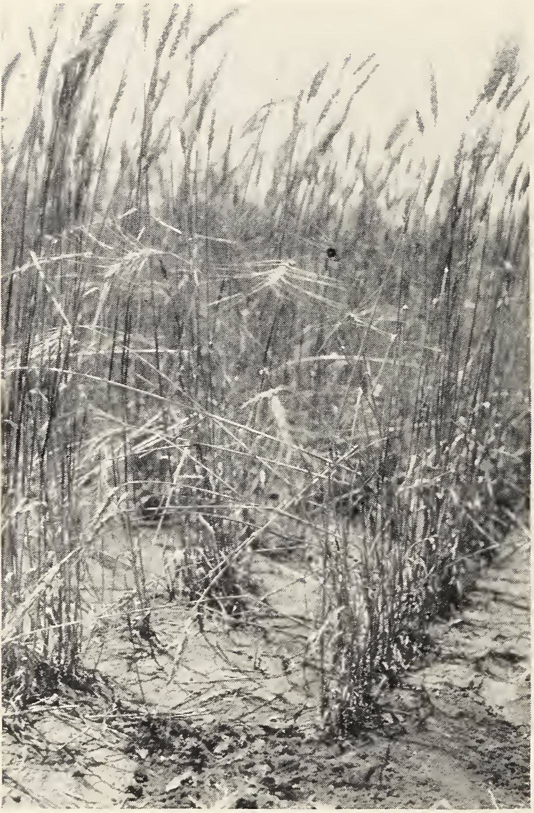

Figure 8.—Buckling of wheat culms caused by the take-all foot rot. Hope, Kans.

Buckling at or immediately above either the top node or the node next below it may occur when rapidly growing winter wheat plants are heading and the weather suddenly becomes hot and dry or when dry hot winds whip them. In such cases the water loss is greater than the replacement, and because of this the succulent growing region of the culms just above the uppermost nodes becomes limp and buckling results. This kind of buckling occurs most commonly in semiarid regions.

FALLING OF CULMS CAUSED BY INSECTS [5]

The insects that cause falling of wheat culms are the hessian fly, wheat jointworms, billbugs, and sawflies, all of which are of wide distribution.

Hessian Fly

The hessian fly (*Phytophaga destructor* (Say)) is widely distributed in the United States and Canada (*16*). The falling of wheat straws caused by this insect occurs usually after the plant has headed. The bent area is a distinct buckle. The first spring generation of the flies causes buckling near the ground line between the joints. The second spring generation may cause buckling higher than the first. The injury due to this generation is often confused with hail, because of the uneven, ragged appearance of the infested field.

When the hessian fly is responsible for straw falling, the cause is easily distinguished by the "flaxseed," or puparial stage, of the insect found singly or in groups at the bending point of the straw between leaf sheath and stem (fig. 9). Where the "flaxseed" rests against the straw, there is

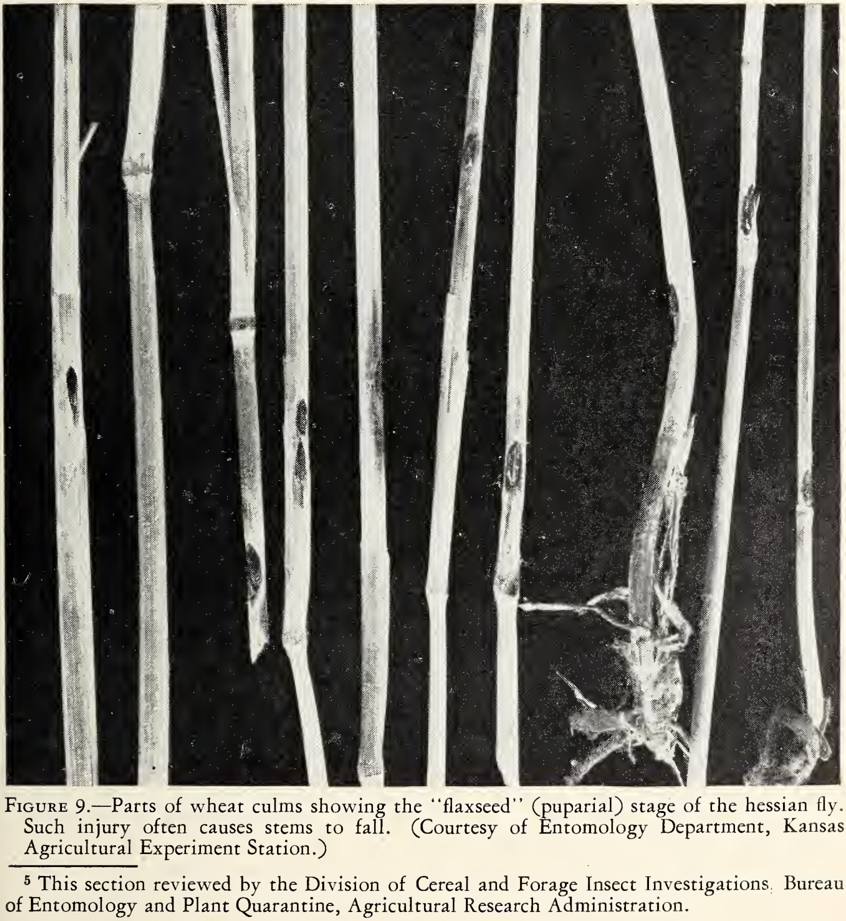

Figure 9.—Parts of wheat culms showing the "flaxseed" (puparial) stage of the hessian fly. Such injury often causes stems to fall. (Courtesy of Entomology Department, Kansas Agricultural Experiment Station.)

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[5] This section reviewed by the Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration.

an indentation, and it is at this point that buckling occurs. Accordingly, hessian fly injury may be identified either by the presence of the flaxseed stage of the insect or by the crease or indentation made in the stem by that stage.

JOINTWORMS

The principal three species of jointworms on wheat in the United States (*11*) are the wheat jointworm (*Harmolita tritici* (Fitch)), the wheat sheath-gall jointworm (*H. vaginicola* (Doane)), and the wheat strawworm (*H. grandis* (Riley)).

The wheat jointworm occurs chiefly east of the Mississippi River and in Missouri but is also firmly established in western Oregon. It has caused considerable damage to wheat in Utah and has been reported in Iowa and Montana. The injury is confined mostly to the part of the culm immediately above the joints, usually the second or third joints above the crown, but it may occur above any joint. The depredation of this pest may be noticed any time within the period from 10 days after heading until harvest. A characteristic symptom that aids in identifying the wheat jointworm is the formation of galls in the stem at the point of attack (fig. 10). These galls, or wartlike elevations, may cause the stems to be distorted. In many instances, however, there is no external evidence of the gall. In any case the attacked tissue is hard and woody at maturity and may be detected by squeezing between the fingers. Falling occurs before the gall tissue hardens, and the buckle may occur either in the gall or just above or below it. The culms buckle under stress of storms. The larva may be found by cutting the straw lengthwise through the gall in which it feeds. If the jointworm adult has escaped from the gall, the exit hole is plainly visible.

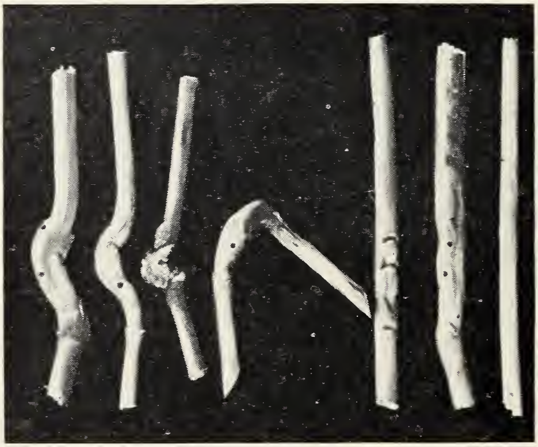

FIGURE 10.—Sections of wheat culms showing typical galls or injury from the wheat jointworm.

The wheat sheath-gall jointworm is injurious chiefly in Ohio, Michigan, New York, and Pennsylvania. This insect is not found inside the culm of the plant, but lays its egg inside the tender upper leaf sheath long before the head emerges. The worm develops in the leaf and causes it first to become fleshy, later hard and brittle. This condition makes it difficult or impossible for the head to emerge. Consequently the upper internode rarely elongates, and as a result the head usually is held in the sheath. No typical lodging of straw is caused by this insect, but the upper node or peduncle may buckle, owing to elongation of lower nodes and the retention of the head in the injured boot (fig. 11).

The wheat strawworm is widely distributed in the United States, occurring to some extent wherever wheat is grown. In its spring form this insect

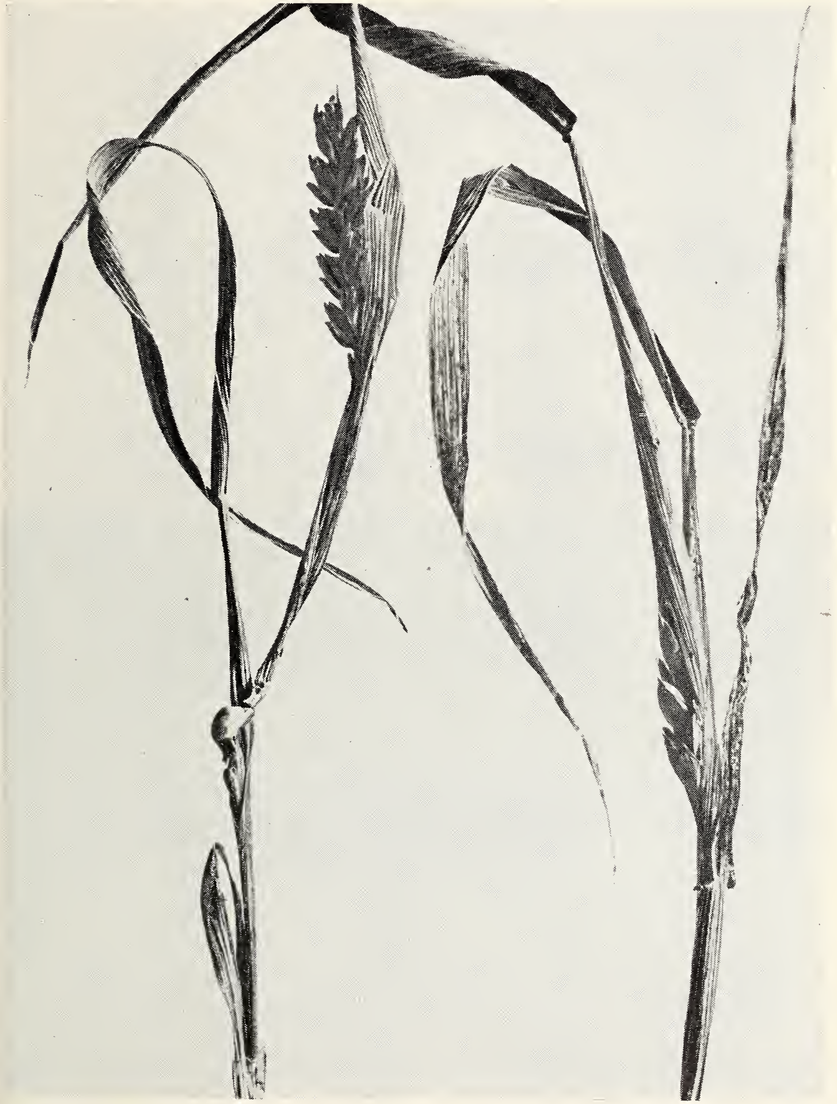

Figure 11.—Wheat culms, showing gall or injury from wheat sheath-gall jointworm. (Courtesy of the Bureau of Entomology and Plant Quarantine, Agricultural Research Administration.)

attacks the young plants and kills the invaded tillers while they are young. The summer form deposits its eggs in winter wheat just above the youngest and most succulent joints, usually after the plant has headed and is in bloom. The larvae embed themselves in the nodes. Some of the infested culms may fall over at these weakened points. The injuries caused by the wheat strawworm should not be confused with those caused by the wheat stem maggot (*Meromyza americana* Fitch) (*6*), which attacks the wheat plant in the heading stage, kills the uppermost internode (peduncle) and the head, and leaves the rest of the plant green. The killed heads turn white but do not fall. The top internode pulls out readily because the larvae of the insect has severed the stem iust above the top node, or joint.

BILLBUGS

Several species of billbugs of the genera *Calendra* and *Sphenophorus* attack wheat (*12*). They are widely distributed in the United States and Canada, especially in regions where the native flora is or was chiefly grasses. The breaking-over of wheat straw when due to the billbugs occurs after the plants begin to ripen and before harvest. The egg is inserted into the culm near the ground line and hatches into a small larva, which feeds inside the lower part of the culm. When the larva grows too large it eats its way out and then feeds on the roots. The exit hole is below the soil line and may be plainly seen when the affected plant is pulled up. The straw may buckle when falling but usually breaks at the exit hole. The interior of injured straw is filled with the frass of the insect, and the walls of the culm are thin (fig. 12).

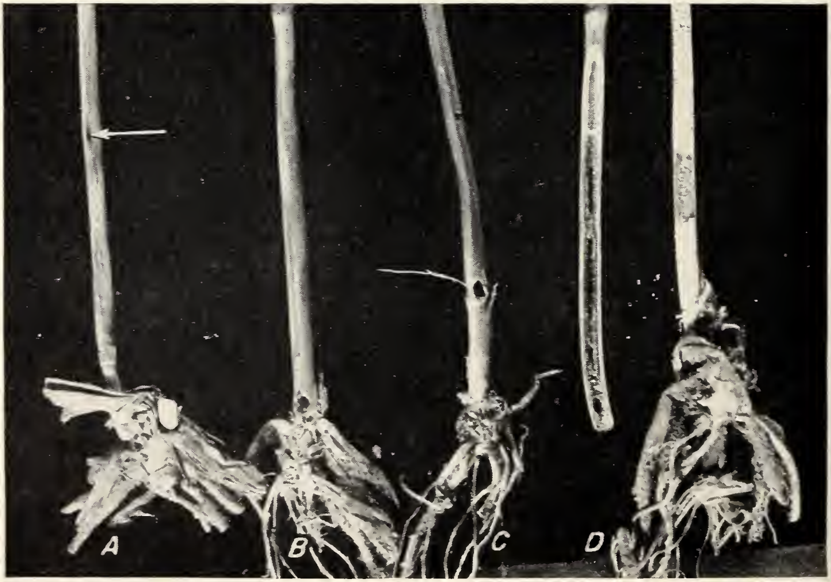

FIGURE 12.—Basal parts of wheat culms injured by a species of billbug: *A*, Point where the egg was deposited (arrow); *B* and *C*, typical exit holes of larvae, the places where the culms usually break; *D*, split culm, showing injury and frass of the larva.

SAWFLIES

The principal three species of sawflies known to attack wheat in the United States are the wheat stem sawfly (*Cephus cinctus* Nort.) (*1*), in the Central and Western States; the black grain stem sawfly (*Trachelus tabidus* (F.)) (*5*); and the European wheat stem sawfly (*Cephus pygmaeus* (L.)),[6] in Ohio and eastward. All three cause a characteristic breaking of culms somewhat different from that discussed up to this point. The insect lays its eggs in the cavity of the culm, and, after these hatch, the larvae make their way to the base of the culm and later saw off the culm from the inside, a little above the surface of the ground. The culms then fall over because of complete severance, usually just before harvest. This falling of wheat straws is sometimes mistaken by the casual observer for work of the hessian fly. It need not be, however, for sawflies cut off the wheat straws, while the hessian fly weakens them so that they buckle wherever they are weakened most by the presence of larvae in the flaxseed stage inside the sheath. The falling caused by the hessian fly may occur near the ground or somewhat higher up, while the sawfly larvae always sever the culms fairly close to the ground.

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